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Applied Mathematical Studies in Risk Management Strategies and Crop Insurance in Agriculture

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Abstract: ***Rural population depends on agriculture that is major source of income for livelihood. The agricultural work is sensitive to variation of external uncontrollable environmental parameters as well as some controllable parameters that are vulnerable to risk on return on investment. The Indian business cycle is influenced by the crop pattern that mainly depends on the vagaries of nature; every flood or drought has its own impact on the Indian economy. Agri-business encompasses whole lot of activities of agriculture sector under one umbrella, like integration of production, processing and marketing. The process starts at the product level and reaches out to the final consumers through vertical integration. Agribusiness favors Indian farmers in every possible way be it policy, climate and several other advantages points that India inherently possess in production. Agricultural insurance is seen as one of the best strategies to address farm risks and encourage farmers to embrace modern production practices with greater potential for better and quality yields. Crop insurance serves as an effective institutional mechanism to cope with production risks. Crop insurance is an important measure/instrument used by farmers for mitigating the financial losses due to various types of natural calamities/risks which damage and destruct the production. The Analysis is based on identifying linkage of agricultural productivity with energy intensity, rainfall and consumption of fertilizer by statistics and mathematical formulation of the system dynamics. In modeling farm systems it is widely accepted that risk plays a central role. Furthermore, farmers' risk aversion determines their decisions in both the short and the long run. This paper presents a methodology based on multiple criteria mathematical programming to obtain relative and absolute risk aversion coefficients.***

Keywords: crop insurance, agricultural productivity, risk, mathematical formulation

1. Introduction

Agriculture which is an important sector of economy is considered widely as an industry. It faces various types of natural hazards. Insurance is an important instrument to give protections under risky activities and that plays significant role in the agricultural production decision, chemical use decision, cultivation practices and cropping pattern decisions. Crop insurance is an important measure/instrument used by farmers for mitigating the financial losses due to various types of natural calamities/risks which damage and destruct the production.

It is also one of the important instruments that can be used by a farmer to stabilize his income against partial or complete crop failure due to adverse weather [such as disasters, flood, hail, drought etc.] or due to related adverse physical crop conditions which are beyond his control.

Before the introduction of crop insurance farmers took crop loan from the different financial institutions, that is, from different formal credit institutions such co-operative credit institutions, regional rural banks and commercial banks. So they became loaned farmers. There were no crop insurance facilities. In that case if the crops were damaged by natural calamities, there was no chance of getting or receiving indemnity from the insurer. After crop damage they were bounded in debt trap.

2. Need for Crop Insurance

The crop production has been subjected to vagaries of weather and large-scale damages due to attack of pests and diseases, crop insurance assumes a vital role in the stable growth of the sector. Crop insurance is a means to protecting the cultivators against financial loss on account of anticipated crop-loss arising out of practically all natural factors beyond their control such as natural fire, weather, floods, pests, diseases etc. The sum insured could be the total expenditure or a multiple of it or a proportion of expected income from crop for which premium is paid. Actual loss in yield or income is not ascertained for eligibility for claims. Crop insurance is one alternative to manage risk in yield loss by the farmers. It is one of the important tools, which helps in reducing the impact of income loss on the farmer. Crop insurance is a means of protecting farmers against the variations in yield resulting from uncertainty of practically all natural factors beyond their control such as rainfall ,flood, hails. Crop insurance is a financial mechanism to minimize the impact of loss in farm income by factoring in a large number of uncertainties which affect the crop yields. As such it is a risk management alternative where production risk is transferred to another party at a cost called premium. The weather based crop insurance uses weather parameters as proxy for crop yield in compensating the cultivators for deemed crop losses. It provides a good alternative both to farmers and government. Rainfall insurance is a specific form of weather insurance. As such weather insurance is not yield insurance while crop insurance is. In both the cases cultivators pass risk in yield to another party for a premium.

3. Objectives of Crop Insurance Scheme

The objectives of crop insurance scheme are:
1. To protect the farmers against the loss of their crops [declared affected crops] due to natural disasters such as hail, drought and flood etc. or the loss of revenue due to decline in the prices of agricultural commodities.

2. To encourage the farmers to use progressive agricultural strategies, high yielding seeds and fertilizers, and to use advance technology in the agriculture.
3. To stabilize the income of the farmers in the years' of natural calamities

4. Need for Study

For having no adequate irrigation facility, farmers depend on nature. The loss of crops due to natural calamities. For this purpose National Agricultural Insurance Scheme (NAIS) has been taken into consideration for the security of the farming and the farmers employed in the field of agricultural.

5. Objective of the Study

Nobody would deny the feasibility of introduction of crop insurance in agriculture. If the crop insurance system is in force the farmers could be easily mobilized to face various hazards in agriculture. They become interested to produce more risky and highly expensive crops with less tension. If the loaned farmers properly utilized their crop loan for productive purpose, their income would have been generated as expected. After crop damage due to natural calamities, if the insured farmers would have the opportunity to recover some part of loss or total loss, they would have been more interested to crop insurance. Thus the crop insurance acts as a safeguard to the farmers.

6. Statistical Issues in Premium Determination in Crop Insurance

Farmers continually face risks in crop production right from the time of sowing to harvesting. Floods may wash away growing fields, droughts may wither plants, diseases and pests may attack during crop growth and rain or hailstorm may wipe out months of farmers' labour and likely production in a single stroke. Crop insurance is a technique of protecting the farmers from such risks. Under crop insurance by paying small amounts as premium, farmers purchase the right for compensation in the event of crop failure. The liability of the Government to bear the cost of relief measures to the farmers following crop failure is reduced to some extent as through crop insurance the farmers themselves contribute to their own relief. In such cases, the statistical issues namely variation in yields, their distributions, determination of premium rates by well known methods and their comparisons have been discussed. The premium rates in a given homogeneous defined area depend on two parameters: (i) year to year variability in the average annual yield (measured in terms of coefficient of variation) and (ii) the level of coverage. The actuarial premium rates are directly proportional to these parameters. Larger the variability, higher is the premium for a fixed level of coverage. Alternatively higher the level of coverage, higher is the premium for a fixed level of variability. The amounts of insurance protection and premium rates should be determined not only by technical considerations alone namely the average yield of a crop and its crop loss probability but also by economic and social considerations like paying capacity of the farmers, the resources that the Government is willing to allocate as also the desirability and feasibility of income transfer from non-agricultural to the agricultural sector.

7. Crop Insurance -Actuarial Framework

The National Agricultural Insurance Scheme (NAIS) launched during the year 2000 has strengthened the scope and coverage of earlier crop insurance scheme. The main objectives of the scheme are:

1) To provide a measure of financial support to farmers in the event of the crop failure due to natural calamities like droughts, floods, pests and diseases etc.
2) To encourage the farmers to adopt progressive farming practices, high value inputs and higher technology in agriculture
3) To help to stabilize farm income, particularly in disaster years thinned the scope and coverage of earlier crop insurance scheme.

The financial risk management is an ingrained component of insurance exercise. The farmers harvesting higher productivity make greater capital investment in terms of inputs and farm practices. The credit needs of such farmers are also greater. This increases the magnitude of financial stakes and in turn vulnerability of financial risk. The actuarial procedure therefore has to guard the interests of such farmers in a rationale manner. If the probability of risk management of high productivity gaining farmers is less than the low productivity gaining farmers then the crop insurance design may be missing its desired objective.

8. Risk and Uncertainty

Risk and uncertainty are generally used synonymously and the events involving anyone of the two relate to the future. But from the economic point of view, they are considered different from each other. Some events can be predicted at least in probabilistic terms. These occurrences can be foreseen on the basis of past experience. Such events are said to involve risk and not uncertainty. In other words, all risks are uncertain, but all uncertainties are not strictly risks. Only uncertainties which can be concretized into specific happenings -past, present or future -can be covered by Insurance. According to Wallet existence of uncertainty is the fundamental condition for the existence of insurance. But uncertainty in abstract form is the state of mind of the individual which correspond to the degree of probability of an occurrence (or chance) in the objective situation. Thus, Uncertainty is a function of probability.

From insurance point of view, probabilities can be divided into three categories: first, those in which a definite mathematical expression of probability can be attained in advance of the occurrence of the uncertain event; second, those in which probability can be obtained in advance and third in which no method of obtaining probability exists.

9. Risk Management Measures

In order to cope with these risks, farmers and rural societies have developed a range of risk management measures.

These can be classified into Risk-reducing and Risk-coping Strategies.

Risk-reducing strategies include crop diversification, inter-cropping, farm-fragmentation and diversification into non-farm sources of income. Crop-sharing arrangements in land renting can also provide an effective way of sharing risks. Risk-reducing strategies can be effective in addressing many production and market risks. But while they help to stabilize family income. They are typically costly for those with average income because they require that farmers forego their most profitable alternatives. For example, Crop diversification is usually less profitable on average than crop specialization and land fragmentation imposes costs in the form of labour and transport inefficiencies.

Risk-coping strategies are relevant for dealing with catastrophic income losses once they occur. Under such circumstances farmers may need new credit (especially consumption credit) the sale of assets, or temporary off farm employment. Risk-coping strategies also prove costly to the farmers. The sale of assets for example affects adversely the long-term growth of a farm business. The loans raised during time of occurrence of catastrophic losses are required to be repaid. And if it is raised from informal sources then it will be quite at a higher rate of interest. But a more fundamental problem with traditional risk-coping strategies is that they cannot deal effectively with the co-variability problem that characterizes most agricultural risks. For example, production and price risks affect nearly all farmers simultaneously in a region. Many farmers seek consumption credit, at the same time, thereby driving up local interest rates. Similarly, local wages are driven down by a surge in the labour supply, and the value of farm assets declines as too many farmers try to sell at the same' time. Once the crises is over, farmers will find it difficult to replace assets as prices are generally go up again because of competition. For co-variate risks, local risk-coping strategies need to be reinforced by risk pooling arrangements that cut across one region to another. Here lies, in fact the role of Crop Insurance which covers all regions of the country.

By means of Crop Insurance, the farmers can insure himself against certain chance of occurrence of crop loss due to weather hazards, insect infestations and diseases. Crop Insurance can be classified into several categories:
(i) Single peril or Multi-peril Crop Insurance
(ii) Individual farm based or area based Crop Insurance
(iii) Specific crop or all crops based Crop Insurance
(iv) Voluntary or Compulsory Crop Insurance

10. Risk Analysis

Probability of risk in agriculture covers the following functional areas -
i. Production Risk
ii. Market risk
iii. Financial risk

The study reveals that probability of uncertainty at each stages of the agricultural work is high because of uncontrollable climate adversity and the controllable reliability in electric supply. Since marketing of agricultural product is depended on production capacity and storing at the warehouse and cold storages, the variation in productivity due to uncertainty will equally affect the marketing subsystem and financial sub system on account of chain reaction. Fertilizer application also need scientific method, unless fertilizer is applied scientifically, there is risk of losing stability in production that is controllable. Financial, marketing and production sub systems are in close loop within the agricultural system, the development of uncertainty at any stage in the sub system will have impact on the other sub system in chain action. Unless agriculture production reaches expected target productivity, there is less probability of further investment by the farmers. The model indicates that deficiency of input to any sub system will have possibility of risk in the functioning of all sub system since production; marketing and financial sub systems are in close loop of the entire agricultural system. Since energy input is controllable that has linkage with irrigation, a better infrastructure will minimize risk. While uncontrollable climate that has linkage with energy resource and irrigation, minimization of risk is also possible by adaptation methods. Energy security becomes well by decentralized power generation from renewable energy resources, specially, utilizing biogas plants technology. The agricultural sub systems are in close loop which are vulnerable to uncertainty but controlling methods by IT, knowledge development programme and better infrastructure will minimize uncertainty.

11. Mathematical Analysis

The relationship between the variables in agriculture and the weather at any region by mathematical method, the important information emerged.

If Yi is yield per hectare of the land, r is the annual rainfall departure in a area and t is the mean temperature, then expected climate in the area for agricultural growth can be expressed as ,

C = r/t > 0, let X is the crop characteristic

$$Yi = A*x + c*Yi + k \quad (1)$$

Where, A= soil characteristic is the co efficient and k is growth supporting application which is a constant.
Since Ci is continuous variable, Marginal effect on crop yield can be expressed as

$$ME = Dy/Dc = fn \quad \ldots (2)$$

After computation of (1) & (2)

$$fn= Yi[c+1]2 \quad \ldots (3)$$

Then marginal change in yield per hectare with marginal change in climate will vary from previous year by a factor [c+1]2, this implies yield per hectare will be affected by square of value in (3) ,that the yield per hectare will decrease if C become< 1, yield will increase if C >1.

The model suggests scientific methods need be included in agricultural support mechanism. This is controllable methods to minimize uncertainty that is increasing knowledge about unknown future events. Firstly the driving input to supporting mechanism need be developed. The uncontrollable climate and weather is different across the country, Long-term weather forecast need be disseminated to farmers by application of advanced Information and

communication technology in collaboration with meteorological department in order to create awareness among the farmers about the impending regional weather situation across the country. Then it is essential to develop information network adopting information technology to disseminate information covering every nook and corner of the rural India, since spreading communication network need infrastructures for energy distribution at the villages.

12. Conclusion

Mathematical programming and risk in the farm model to address the effect of crop insurance and environmental payment on the farmers' production behaviour has been implemented. If agricultural subsidy and risk management policies have the potential to alter land use, cropping practices, and conservation practices, they may contribute to increases in soil erosion. Limited success in traditional crop insurance schemes is attributed to the financial non aviability due to non actuarial based premium as well as the serious problem of moral hazard, adverse selection and complex administrative procedures. In contrast the weather indexed insurance schemes would result in financial viability for the insurer by effectively transferring his risk to the investors in the secondary capital market and eliminating adverse selection and moral hazard problems while reducing administrative costs by using an objectively calculated index. The research could expand the knowledge of climate risks in agriculture by means of deeper and more comprehensive studies on climate events and trends as well as on physical and socio-economic impacts and risk management options.

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Author Profile

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